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# Group Effectiveness Research Laboratory

DEPARTMENT OF PSYCHOLOGY · UNIVERSITY OF ILLINOIS · URBANA, ILL

## METHODS OF ANALYZING GROUP TASKS


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Communication, Cooperation, and Negotiation in Culturally Heterogeneous Groups
Project Supported by the Advanced Research Projects Agency, ARPA Order No. 454
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## ABSTRACT

In this report, it is argued that description and classification of group tasks can best be approached from a theoretical rather than empirical or factor analytic perspective. It is pointed out that previous attempts at task classification generally focus on one of three aspects of the task and group situation. The literature of group task analysis dealing with each of these aspects is then reviewed, and it is pointed out that each kind of task classification can be comprehended as an attempt to discriminate different relations existing between various elements of the task and group structure. The contribution of these attempts to a theoretically useful taxonomy of tasks is evaluated.

Structural role theory is introduced as a theoretical framework which leads to a system for classifying tasks. Digraph theory and matrix algebra are then applied to the problem of task definition, and indices for the measurement of some important group task dimensions (inter-position collaboration, inter-position co-ordination, inter-task co-ordination, and goal path multiplicity) are derived. The report concludes with a brief discussion of the problems and advantages of application of the structural role theory method of task analysis.

## Methods of Analyzing Group Tasks[1]

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Earlier work by Fiedler (1965) shows that the perform nce of culturally heterogeneous groups is determined partly by the nature of the group task. Homocultu al groups perform better than heterocultural groups only on certain tasks. This finding suggests that task characteristics deserve closer attention. It would be desirable to know what kinds of task are likely to produce differences in performance between homocultural and heterocultural groups. Fiedler has so far classified tasks along a structural dimension (structured-unstructured). It is possible that other task dimensions will be important for the understanding of group process (e.g., co-operation requirements, difficulty). This report will therefore consider some possible ways of classifying tasks and provide a method of analysis which should be useful in subsequent research on the determinants of group effectiveness.

### I. The Purpose of Task Analysis

The literature of small groups and organization theory, has, during the last fifteen years, provided a number of reasons for studying group tasks.

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These may be briefly listed:

(i) Taxonomy. In personality analysis, persons are described and compared using a number of general categories and dimensions. The classification of personality types is a necessary prerequisite for the precise statement of hypotheses and generalizations concerning the relation of personality to specific behaviors. Similarly, the statement of categories and dimensions of group tasks should provide a way of identifying different task types and a way of comparing their differential effects on group behavior.

(ii) Generalization. Studies in social psychology are carried out in specific situations, whether these be in the laboratory or in natural settings. Results obtained from these studies are often applied to other situations without a careful examination of the validity of such extrapolation. The appropriateness of generalizations should be decided upon after a consideration of the degree of resemblance between the significant features of the situations involved. One of the significant features common to all group situations is the task, and task analysis would therefore help social psychologists to evaluate the generalization range of their findings. Findings derived from studies in the laboratory, for example, may not be directly applicable to actual organizations because there are marked differences in the tasks which are performed in the two settings (Golembiewski, 1962; Weick, 1965).

(iii) Theoretical integration. If the task of a group is to be treated seriously, and not just dismissed as a difficult situational variable which needs to be controlled, then a way of relating task characteristics to other elements of group structure is needed. Task analysis would provide a means of meeting this need. Many writers have emphasized the importance of task analysis for theoretical integration in social psychology (e.g., Carter et al., 1950; Roseborough, 1953; Roby & Lanzetta, 1958; Hare, 1962; Shaw, 1963; Oeser & Harary, 1962, 1964; Anderson & Fiedler, 1964; McGrath, 1965; McGrath & Altman, 1966).

(iv) Description. Inclusion of task analysis in a conceptual scheme should help to interpret and explain a wider range of findings. It should also lead to finer description of group behavior. Different activities may be associated with different aspects of group structure. Where task is treated as a major element of group structure, then observation of group activities will distinguish activities largely associated with task performance from activities which constitute interpersonal behavior. Thus, Bales (1950) distinguishes task functions from socio-emotional functions in his method of process analysis. Task activities are also deliberately separated from "personal" activities in the research of Herbst (1952, 1953); Wilson, Trist & Curle (1952); Rice (1958); and Trist et al., (1963). This separation forms the basis for a comprehensive behavior description which, in turn, is the foundation of a theoretical structure which relates task analysis to social behavior.

## II. Possible Types of Task Analysis

Analysis of group tasks involves an examination of the ways in which the task can be related to other features of the group structure. In some ways, this analysis is similar to the method of describing the meaning of a theoretical term. The main similarity stems from the "relational" quality of tasks and theoretical terms. A theoretical construct is related to other theoretical constructs, logical terms, and data terms by a set of syntactic and logical rules. Specification of these rules describes the actual and possible ways in which the construct is connected to other elements of the theoretical system. In this way, the meaning of the construct is demonstrated. Similarly, the analysis of a task is given by describing the permissible relationships between it and other elements of group structure.[2]

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[2] It is possible to analyze tasks in a purely empirical or atheoretical manner. For example, Hackman (1966) and Morris (1965) classified tasks in terms

Considered in this way, task analysis is inevitably associated with a set of concepts of group structure and relationships. Whatever set of concepts is used to describe groups, reference is made to two aspects of groups (other than tasks). These aspects are associated with persons who are members of the group, and an organization which structures the relationships between persons. Using these general and rather vague notions of persons and organization, types of task analyses may be described.

(a) Task-task analysis. Here the task is considered in relation to itself. The task is considered as a system with component parts and relations, and particular tasks are described in terms of a particular "configuration" in the component parts.

(b) Task-organization analysis. In this kind of analysis, a particular task is described through examination of the relationships holding between the task system and the organizational structure.

(c) Task-person analysis. The final kind of task description is achieved when characteristics, abilities, and states of persons are related to specific characteristics of the task.

At present, these types of analyses will not be examined in detail. This

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of qualitative descriptions of the task instructions ("produce" or "discuss" or "solve"). These descriptions did not state any relationship to group structure and this was done deliberately, for they tried to determine the consequences for group structure and behavior of the task types. Their work must therefore be viewed as a prelude to task analysis. The approach of Altman (1966a, 1966b) is also an empirical one, although he does use an arbitrary classification scheme for describing task behavior. Altman maintains that the analysis of group tasks should be based on a classification of the group behaviors which they produce. Hence, the complete analysis of group behavior must await the result of systematic studies of the relationship between tasks and group behavior. The importance of relating task analysis to behavior cannot be disputed, but it appears that this can be best done when there is available a way of describing tasks independently of group behavior.

will be done in the course of a review of current methods of analyzing tasks. They are mentioned at this point because they serve, firstly, to illustrate what is meant by the "relational" quality of task analysis, and secondly, because the three types help to classify existing methods of analysis. The following brief review of methods of group task analysis will reveal that most methods can be classified as belonging to one or another of the three types above.

## III. Review of the Literature on Group Task Analysis

This review has two aims. The first aim is to organize existing methods of analyzing group tasks. The second aim is to evaluate the contribution of the various types of analysis to the construction of a general taxonomy of tasks which is, at the same time, theoretically useful. It is realized that most of the schemes and classifications to be considered were constructed for immediate and specific purposes. So, in some ways, any criticisms of these approaches will be unfair. Lafitte is correct when he states that "any scheme of job description, analysis or classification is as good as any other so long as it serves its purpose" (Lafitte, 1958, p. 66). However, it is still reasonable to see if purposes other than those intended are also achieved. Any criticism made then, in the course of this review, does not imply that the relevant analysis is unsatiffactory when judged against its own aims.

### Task-Task Analysis

Because of the "individual" orientation of social psychology, there are few accounts which treat tasks independently of persons and group organization. Task-task analysis is characterized by a concern with the division into sub-tasks and the relationships which order the sub-tasks. In the study of flow charts, or work study, the group's (or organization's) goal is broken up into a set of sub-tasks or "operations" which are ordered by temporal relationships with various modalities. The temporal relationships indicate the order of precedence for the sub-tasks while the modality refers to whether a sub-task "may" or "must" occur after a certain sub-task. In critical path analysis (Shaffer, Ritter & Meyer, 1965), the group task is split up into sub-tasks which are then given an estimated completion time. The sub-tasks are then connected by lines which represent precedence relationships on the sub-tasks. After these relationships have been specified, a "critical path" joining the sub-tasks is calculated. This path shows the most efficient way in which the total task can be completed. Work engineers are interested in this method of task analysis because efficiency is increased and costs lowered. Occasionally this kind of task analysis in a simple form is used by psychologists. For example, Guest (1962) observed that poor productivity and negative social relationships in an automobile factory were partly due to inappropriate sub-task engineering on the assembly line. Another example is given by Katz and Kahn (1960). In considering what leadership style was effective for supervisors, they used an analysis of the work group task which described it in terms of two sub-tasks----planning and actual operation on materials. Both of these examples refer to instances where the investigator used a simple type of task-task analysis for the purpose of understanding social behavior in a specific situation. Analyses which are general in their application are much rarer in occurrence. One example of a general approach is Roby's treatment of sub-task phasing in small groups (1962). Roby was concerned with the problem of defining and ordering task segments and the consequences of particular task phasing for group behavior.

Task-Organization Analysis

The second kind of group task analysis is largely concerned with describing how tasks may require the group to organize its activities in various ways.

Within this class of analysis, two major types may be discerned. The first type is based on a mechanical input-output model, while the second type describes the task in terms of co-operation requirements. The input-output analysis will be considered first.

(i) <u>Group task analysis in terms of input-output variables.</u> Several studies by Lanzetta and Roby on group task performance were followed by a theoretical paper on the analysis of group tasks (Roby & Lanzetta, 1958). In this paper, they proposed a method of describing "group-task" characteristics. Essentially, each task provided an "input" to a group which had to be dealt with in a certain way if a specified state of the physical environment was to be changed or maintained. The performance of the task could be described using four different sets of "events" (task input, group input, group output, task output). This description of the group-task system is depicted schematically in Figure 1 (after Roby & Lanzetta, 1958).

Event Sets

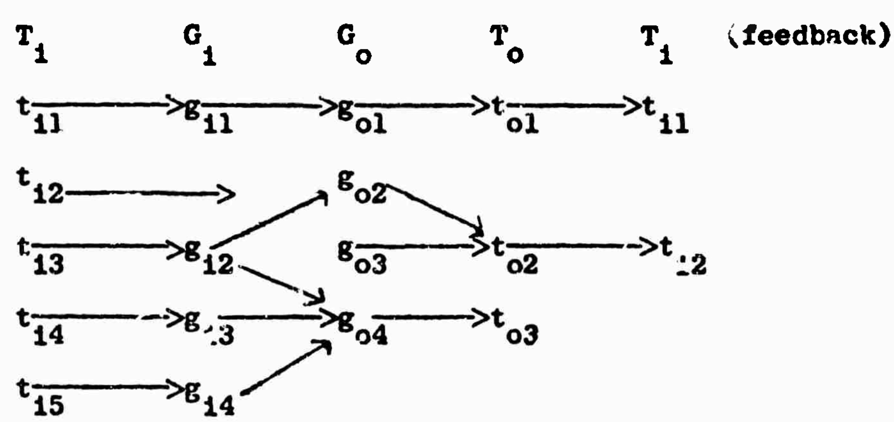


Figure 1.

Roby & Lanzetta's paradigm for the description of group tasks

The set of events ($t_{i1}$, $t_{i2}$....) occurs in the general surroundings of the group and the entire class of such events is denoted by $T_i$ ("the class of task input variables"). Examples of the events given include variation in "input displays," and stress-inducing stimuli. $G_i$ designates the class of group input activities which occurs within the group as a consequence of $T_i$. Examples include attending or observational responses. Following the occurrence of activities in $G_i$, there occurs group output activities ($G_o$). These responses lead to a further class of events ($t_{o1}$, $t_{o2}$....) in the external environment. These events constitute the class of task output variables $T_o$. Some subset of events in $T_o$ generally forms the basis for evaluation of group performance.

Roby and Lanzetta link the group input and output events to certain positions in the group. Complete task description then involves the specification of the appropriate task events $T_i$, together with the distribution of $G_i$ and $G_o$ activities which are associated with the various group positions. This task analysis then involves the description of the "physical" properties of the task, specification of the group "activities" required, and listing of the ways in which these activities are allocated. At a later stage of their article, they consider that tasks can be further described in terms of more abstract organizational requirements. Those requirements are called "critical demands" and are of three types. The first demand is <u>orientation</u> which denotes the function of determining the condition of variables in the task environment. The second demand is <u>mapping</u>, "the process by which a group anticipates or learns the consequences of various action alternatives under various environmental conditions" (Roby & Lanzetta, 1958, p. 96). The final demand is <u>jurisdiction</u>, and this refers to the processes whereby response actions are chosen and decisions implemented.

This analysis stresses the close relationship which exists between a group task, group organization, and individual activities. Furthermore, it maintains that group tasks may be characterized by the group processes which they induce (or "demand"). Its usefulness as a method of task analysis, however, appears limited because (a) of the lack of clarity in key terms like "event" and "action," (b) the "input-output" dichotomy does not provide a means of analyzing the sets of behaviors that intervene between the reception of information and the final goal achievement activities (for instance, how are these activities understandable in terms of structural dimensions such as power and communication?), (c) no information is given about the dimensions used for describing task variables, (d) the analysis seems to be applicable to only a limited number of tasks. These are tasks which require individuals to deal with changing sources of "information" according to a clearly defined set of observations and procedures.

Another analysis which classifies tasks in terms of their requirement for organization is that of Christie (1956). The task is viewed as a problem in information handling; as an input and output to the group, it is described by its content, form, time, and locus. The task is also defined by the operational modes imposed on the group, and by the organizations developed by the group. Like the analyses of Roby and Lanzetta, group organization is evaluated through assessing its information handling characteristics. This approach tends to neglect the systematic study of the organization as a determinant of task performance. Either the organizational structure is defined by its information processing functions without description of the organizational structure as a system independent of task, or else only one type of organizational structure is treated. This latter procedure is adopted by Christie who concentrates on the communication structure. Another similarity of the Christie analysis to that of Roby and Lanzetta is in the small range of tasks to which it can be applied. Tasks involving the synthesis of elements of verbal or written information are the concern of Christie's analysis, and it has been applied only to the kind of task traditionally used in the communication network studies (Bavelas, 1950; Leavitt, 1951; Shaw, 1964).

(ii) Group task analysis and co-operation requirements. A number of writers have described tasks by examining the type of allocation required for task performance (Lewis, 1944; Thomas, 1957; Kelly & Thibaut, 1959; Fiedler, 1964; McGrath, 1965; Weick, 1965).

(a) Cumulative interdependence. This kind of interdependence occurs when the product which one person produces becomes the input for another person. Assembly line tasks typically have high cumulative interdependence. The standard of task performance of any person is limited by the quality of the input which he receives. Group tasks of this type are described by Lewis (1944) using the terms "specialization of labor," while Thomas (1957) refers to this type of interdependence in terms of high "facilitation in means control."

(b) Disjunctive interdependence. Disjunction exists when group task accomplishment depends on one person in the group performing the appropriate task. Once this task is completed by one person, the group task is also completed (Thibaut & Kelly, 1959, p. 62). The appropriate action does not necessarily depend on any prior sub-task performance. A disjunctive task requires minimal interdependence. Because only one person needs to produce the solution, "a disjunctive task permits group members to work independently without communication or coordination of their efforts" (Thibaut & Kelly, 1959, p. 163)

Examples of disjunctive tasks would be presented where there are group tasks requiring one "correct" solution, e.g., in logical or planning tasks. A group of advertising executives convened to choose a new slogan for a product, has high disjunctive interdependence.

(c) Conjunctive interdependence. With a conjunctive group task, all members have to make a specific response if the group is to succeed (Thibaut & Kelly, 1959, p. 162). With this type of task, each person must complete his sub-task, or else the group is unproductive. When a group is required to achieve consensus in its opinions or attitudes, then conjunctive interdependence is high.

Analysis of tasks using the idea of interdependence focuses on the way in which sub-tasks are distributed amongst persons or positions in a group. This kind of task analysis is especially promising for the study of interpersonal relationships in work groups. The types of informal relationships (e.g., affective, communicative) which are found may be easily related to the kind of group task and its associated type of interdependence. There are a number of difficulties in this type of analysis, however, which need to be met before it can be rigorously applied to the study of group performance. One difficulty derives from the fact that group tasks often require various combinations of interdependence. Another difficulty is due to the classificatory nature of this analysis. Eventually, the analysis should provide a way of measuring the amount of a given kind of interdependence present in a particular group task. At present, group tasks are merely assigned to one or another of the specified categories.

Task-Person Analysis

A group task may be related to persons in a number of ways. Firstly, a group task may require that group members possess certain skills or abilities. Secondly, the group task may determine to a large extent the number and kinds of activities in which a person engages. Thirdly, a group task may affect the opinions and attitudes of persons. These attitudes may be related directly to the task or to other persons involved in the task situation.

Analysis of tasks which concentrate on the task-person relationships are found mainly in the writings of industrial psychologists who have been preoccupied with the problem of fitting a person, or a group of persons, to the work task. A common approach is known as job analysis where the activities of workers are studied without direct reference to the job or product involved (Palmer & McCormick, 1961). McCormick's work involved application of factor analysis to description of worker activities associated with various jobs. His results suggested that the variety of human work activities could be identified or measured using a relatively small number of independent dimensions.

The description of "activities" is a first step to the specification of skills required for a group task. If a group task requires some people to perform arithmetical operations, then some persons assigned to the group should be skilled in arithmetic. Thus, tasks have also been analyzed by listing the skills required in the persons assigned. Personnel managers and vocational guidance officers have their particular "job requirements" lists, but more general classificatory systems have been developed which attempt to organize job requirements using a limited number of independent dimensions (Coombs & Satter, 1949; McCormick, Finn, & Scheips, 1957).

This way of describing tasks complements the previous task descriptions through its emphasis on the effect of personal characteristics on task performance. Task performance is influenced not only by the formal task structure and the group organization associated with this task organization. It is also affected by the distribution of personal characteristics and skills required for its completion. It may also be characterized by the degree to which the skills required by the task are matched to the abilities of the group members. One way of describing this matching is by saying that the task is more or less <u>difficult</u>. Difficulty level has been used by Morrissette, Pearson, and Switzer (1965) to define task types. They defined difficulty levels using a mathematical formula for entropy. In information theory, entropy defines the degree of randomness of events emitted by an information source. Entropy values obtained using information theory definitions were taken as measures of task difficulty.

By using a particular task in various communication nets, Morrissette et al. found that their definition of task difficulty corresponded closely to task difficulty as qualitatively defined. This analysis of task properties should make possibly a more precise study of the interactive effects of task difficulty, task load, and communication structure upon group performance. Its range of application, however, appears to be limited to communication network studies. The analysis deals with but two dimensions, difficulty and task load, and is appropriate only for tasks which have an objective solution attained through the exchange of "information" among all members of a group.

A final way of describing tasks through their relationship to persons, focuses not on personal skills and activities, but on internal states and needs. A task may facilitate or hinder a person in his attempt to satisfy or express certain needs. These methods of task analysis have been employed by workers of Tavistock Institute in their discussion of "socio-technical" systems (Trist & Bamforth, 1951; Rice, 1958, 1963; Emery & Trist, 1960). These sriters describe task organization not only in relation to productivity, but also in terms of its effect on personal satisfactions. Thus, Rice (1958, ch. 4) characterizes primary work tasks by assessing the extent to which (a) the task allows those engaged on it to experience the completion of the "whole" task, (b) the task allows those engaged on it to control their own activities, and (c) the task allows workers to form satisfactory personal relationships.

A number of other writers, working independently, have also defined tasks in relation to personal satisfaction, and they provide further evidence for believing that the criteria listed by Rice not only differentiate tasks, but they are also the criteria which the worker himself associates with job satisfaction. Lafitte interviewed, from different factories, a large number of workers who performed a range of jobs (Lafitte, 1958, ch. 4). Results showed that job satisfaction was significantly related to the worker-defined dimensions of cleanness, completeness (Rice's criterion (a) ), and independence (criterion (b) ). Using these criteria, Lafitte was able to construct a classification of jobs. Dealing with a narrower range of factory jobs---those involving repetitive operations--Baldamus noted that workers gained satisfaction due to a task property which he termed "traction" (Baldamus, 1961, ch. 4). Different kinds of traction were postulated, but the ideas of "independence" and "completeness" were closely associated with all forms.

Tasks have been related to personal satisfaction in the laboratory setting also. The significance of task "completeness" for personal satisfaction has been studied in the course of research into the Zeigarnik effect, while the "control" dimension of tasks has been related to task performance by Trow (1957), using a concept of "autonomy," and by Mulder (1959) who used a similar concept--"self-realization."

The description of tasks in terms of their consequences for personal satisfaction has been used successfully in the development of productive work groups, but so far the task description is linked too closely with the specific situations which were studied. A general, abstract account would take the analysis further by identifying what objective characteristics of tasks are related to personal needs. Also, in many instances, it is not clear whether "the task" refers to the organization of the sub-tasks, or the cross-organization between the sub-task pattern and other properties of the group, like power and communications structures.

Another difficulty concerns the application of this task analysis to group tasks. It is fairly clear that sub-tasks can be classified by reference to general needs and worker satisfaction. But a group task is composed of a set of sub-tasks. If each sub-task is classified differently, using this task-person analysis, how is the group task, considered as a set of sub-tasks, to be classified?

If a group task has four sub-tasks and two of them allow a worker a large amount of control, whereas the other two give the worker little control, then the group task might be classified as one which gives group members a medium amount of control over their own activities. This single measure would obscure, however, the differences among sub-tasks. It is probable that knowledge of such differences in sub-tasks would be more useful in explaining task performance than a holistic rating of the group task.

Scale Analysis of Group Tasks

A method of task analysis which is not easily fitted into the previous classification is scale analysis. Shaw (1963) used a technique for scaling group tasks which is similar to that used by Thurstone and Chave (1929) for attitude scaling. Ten dimensions of group tasks were postulated and 104 tasks were scaled on each dimension. After two successive factor analyses and on certain theoretical grounds, six task dimensions were retained. They were defined as follows:

A. Difficulty -- the amount of effort required to complete the task.

B. Solution Multiplicity -- the number of possible solutions deemed to be correct. This dimension also included the number of alternatives for task completion (goal path multiplicity) and the degree to which accpetable solutions can be verified (i.e., demonstrated to be correct).

C. Co-operation Requirements -- a measure of the degree to which integrated action of group members is required to complete the task.

Shaw found that dimensions A, B, and C were the most stable. Other dimensions were:

D. Intellectual Manipulative Reauirements -- the ratio of mental tc motor requirements.

E. Population Familiarity -- the extent to which the task is encountered by members of the "larger" society.

F. Intrinsic Interest -- the degree to which the task in and of itself is interesting, motivating, or attractive to the group members.

Four of Shaw's original ten dimensions (decision verifiability, goal path multiplicity, solution specificity, goal clarity) were used by Fiedler (1963, 1966) to define the degree to which a group task is structured (its degree of clarity or ambiguity). Shaw's task dimensions differ in type. Dimension B (solution multiplicity) is defined by the formal or objective structure of the task. Other dimensions (A, D, E) are defined by the skills and knowledge required by the group members, if the task is to be completed. Dimension C is defined by aspects of group organization required if the task is to be completed, while Dimension F is defined by one of many possible attitudes to the task.

Scale analysis has resulted in the specification of task dimensions which refer to a number of different ways in which the task can be related to group organization and member characteristics. These dimensions are stated very broadly, and it seems that further development should be in the direction of establishing a set of concepts, this set allowing the relationships between task and group structure to be more finely described.

This review of the literature on group task analysis has shown that the task can be defined by a set of relationships connecting the task structure to other elements of the group. For the purposes of a comprehensive analysis of tasks, most of the classifications referred to deal with a limited number of relationships. This deficiency is only partly explained by reference to the practical or more limited concerns of the authors. It is also explained to some extent by the absence of a conceptual scheme which defines the major elements and relationships of group structure. If such a scheme were available, then a task analysis could be constructed which was both comprehensive and precise. Also, content and precision could be given to the "field" or "system" character of group structure. The value of a precise method of group description for the development of a comprehensive task analysis will be shown in the next section.

## IV. Task Analysis in Structural Role Theory

Having discussed the significance of the task system for the theory of group structure, and reviewed some of the inadequacies of the literature, we shall now use structural role theory to outline a system for classifying tasks and defining some of their properties.

A structural role analysis of tasks endeavors to define a task in terms of the totality of relations included in a structural role digraph. The two earlier papers on structural role theory (Oeser & Harary, 1962, 1964) defined "group structure" in terms of three elements and five types of relations. The three elements[3] defined are:

task -- a primitive term meaning anything that has to be done (which thus can include "mental" tasks);

person -- defined as a human being who has no relationships to other human beings except for those laid down by the rules of his office, and no characteristics other than those prescribed for assigning him to the occupancy of a given position;

position -- defined as a location on an organization chart, a concept

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[3] The three elements defined correspond to the three dimensions of the group-task situation which are used by Fiedler (1964). These dimensions are task structure, leader acceptance (interpersonal) and position power.

which gains its meaning through being connected (a) to persons by assignment relations, (b) to tasks by the allocation relation, and (c) to other positions by the power relation.

The terminology of digraph theory was used to illustrate and describe how any given sets of these three elements may be logically interrelated. The terminology used in structural role theory is summarized schematically in Figure 2 (after Oeser & Harary, 1962).

This postulated set of elements and relations is used to create "ideal type" group structure[4], similar in kind to the institution "ideal types" described by Max Weber (1949). Ideal types, when given empirical interpretation through a set of co-ordinating definitions, are powerful devices for the comparative analysis of group structures and processes.[5]

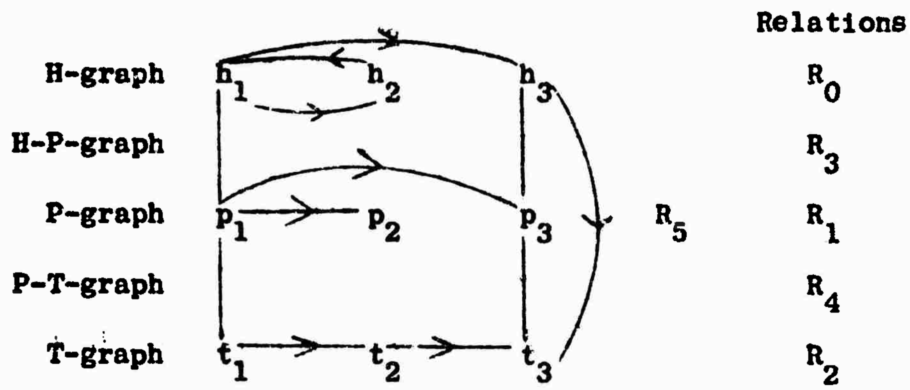


Figure 2.

The schematic digraph, D, of a Structural Role System
(after Oeser & Harary, 1962)

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[4] Ideal types, like mathematical models, are used to represent, at an abstract level, the underlying logical structure contained in a set of descriptive statements. The postulated set of elements and relations provides the abstract categories to be used in constructing specific, yet abstract ideal types. Ideal types are created for "real" kinds of groups (e.g., "bureaucratic" groups, factory groups, school groups) when a particular ordering of elements by the relations is used. Ideal types are unlike mathematical models in that they are generally constructed from observations of empirical reality. Objects and relationships are abstracted from concrete events in order to provide a logically consistent, "idealized" description of that type of event.

[5] See Bendix (1962), and Martingdale (1959).

Terminology for Figure 2

$D$ = the digraph of the role system

$H = h_1 \ldots h_n$ = the set of persons

$P = p_1 \ldots p_n$ = the set of positions

$T = t_1 \ldots t_n$ = the set of tasks

$R_0 = R_{00}, R_{01} \ldots R_{0n}$ = the set of informal social relations

$R_1$ = the power relation

$R_2$ = the task precedence relation

$R_3$ = the person assignment relation

$R_4$ = the task allocation relation

$R_5$ = the induced relation, persons to tasks

For the axiomatic definition of these relations, see Oeser and Harary (1964).

In structural role theory, the analysis of group tasks is carried out by considering the possible ways in which the group goal can be related to the total set of elements and relations. Hence, the major advantages of this conceptualization are firstly, its ability to relate a part of the group structure (the task system) to the total structure. Content and precision can thus be given to the "field" or "system" character of group structure. Secondly, because a formally adequate definition of structure is given, it is logically possible to describe group processes over time in terms of the sets of relations on the elements. Thirdly, specifying the set of relations enables a classification to be made of the type of relations connecting the tasks.

In any task analysis it is necessary to distinguish between five aspects:

(i) The formal analysis of the task: this consists intially of specifying the number of sub-tasks and the set of precedence relationships (Oeser & Harary, 1962, 1964) which may be used to order the sub-tasks. ($R_2$).

(ii) The group organization required by the task: this requires specification of what task elements are allocated to what positions ($R_4$), and the types of power structures ($R_1$) required for task completion.

(iii) The skills and knowledge required to do the task. ($R_3$).

(iv) The attitudes which the individual members may have to the task. ($R_5$).

(v) The individual's perception or "image" of the task, which may differ markedly from the actual task, or from how the individual's super- or subordinates perceive it.

The rest of this report will consider some of the possible task relations and outline some formal operations which provide a basis for the comparative analysis of group tasks.

3. <u>The Person-Task Relations</u>[6]

Suppose two persons, $h_1$ and $h_2$, have been assigned to three positions, $p_1$, $p_2$, $p_3$, and five tasks have been allocated to these positions in the manner shown in Figure 3.

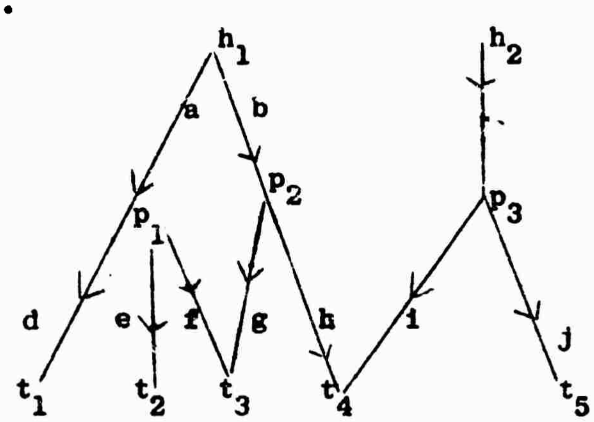


Figure 3.
Digraph of a Role System

Let numerical weights be given to the relationships in $R_3$ (the rules of assignment) and $R_4$ (the rules of task allocation). The weights must be expressed so that the following conditions are met:

$$a + b = 1,\ c = 1,\ D + e + f = 1,\ G + h = 1,\ i + j = 1.$$

[6] The content of this section is derived from a joint paper by Oeser and O'Brien in <u>Human Relations</u>, (in press).

The relations $R_3$ and $R_4$ may now be represented in matrix form. The matrix $M_3$ representing the $R_3$ relation is:

$$M_3 = \begin{array}{c} \\ h_1 \\ h_2 \end{array} \begin{array}{c} \begin{array}{ccc} p_1 & p_2 & p_3 \end{array} \\ \begin{bmatrix} a & b & o \\ o & o & c \end{bmatrix} \end{array}$$

while the corresponding matrix $M_4$ for $R_4$ is:

$$M_4 = \begin{array}{c} \\ p_1 \\ p_2 \\ p_3 \end{array} \begin{array}{c} \begin{array}{ccccc} t_1 & t_2 & t_3 & t_4 & t_5 \end{array} \\ \begin{bmatrix} d & e & f & o & o \\ o & o & g & h & o \\ o & o & o & i & j \end{bmatrix} \end{array}$$

Their product $M_5 = M_3 \cdot M_4$ gives an induced relation $R_5$ with domain H and range T. Oeser and Harary (1964, p. 11f) illustrated the usefulness of this operation for obtaining the induced relation of time distribution of people directly to tasks (by eliminating positions).

This kind of analysis can be used for other purposes. It is possible to specify attitudinal relations between persons and tasks. Consider the relation of "valuing." This is an "informal" relation which is established when an individual starts working at a task. Assume that $h_1$ has $n_1$ tasks and that the measures of the intensities of valuing are $v_1, v_2, \ldots, v_{n_1}$. These measures can be transformed so that $\sum_1^{n_1} v_1 = 1$. Similarly, for the $n_2$ tasks of $h_2$, etc.

The adjacency matrix of valuing, $M_v$, can now be written out for persons-tasks and this can be directly compared with the induced matrix $M_5$. Recall that $M_5$ defines the apportioning of time by each person $h_1$ to each task element

$t_k$ as computed from the explicit structural rules of the organization. $M_v$ defines the apportioning of "valuing" as experienced by each $h_i$ for each $t_k$.

Consider the numerical examples of two matrices $M_5$ and $M_v$ (the $M_5$ matrix is taken from p. 14 of Oeser and Harary (1964) ).

$$\begin{array}{rl} & \begin{array}{ccccc} t_1 & t_2 & t_3 & t_4 & t_5 \end{array} \\ M_3M_4 = M_5 = \begin{array}{c} h_1 \\ h_2 \end{array} & \begin{bmatrix} 50 & 50 & 0 & 0 & 0 \\ 0 & 40 & 42 & 16 & 2 \end{bmatrix} \\ M_v = \begin{array}{c} h_1 \\ h_2 \end{array} & \begin{bmatrix} 20 & 80 & 0 & 0 & 0 \\ 0 & 40 & 10 & 40 & 10 \end{bmatrix} \end{array}$$

Both matrices, $M_5$ and $M_v$, are ways of representing the person-task-relationships within a group. The first relation, $M_5$, is formal, the second informal. The properties of these relations can be investigated through further operations on the matrices; and each relationship in $M_5$ can be compared with each relationship in $M_v$. (For example, one might enquire what consequences follow from the fact that although $t_1$ and $t_2$ have "time-weights" of 50, 50 for person $h_1$, he nonetheless gives them "value-weights" 20, 80).

In the same way, each person can rate his liking for his various positions. If he has one position only, the measure of his liking (at the first level of psychological analysis) will perforce be 1.0. If he has two positions, he may apportion his liking in the ratio o.6 to 0.4 and so on. Whatever rating measures are used, they can be transformed so that their sum is equal to 1.0. The adjacency matrix of "valuing" can be written for person-positions. This can be compared with the adjacency matrix of positions-tasks, in which positions are assigned "weights" by the rules of the organization. That is, the rules lay down what proportion of time is to be spent on each of the task elements allocated to a given position, and these proportions indicate the "weight" or "importance" of each task element. It seems reasonable to assume that discrepancies and fluctuations in productivity will be connected with discrepancies in the "valuing" weights attributed by persons to their positions and their tasks, and the task "weights" attributed to tasks by the rules of the organization.

2. Position-Task Relations

The task allocation relation, $R_4$, orders the set of positions and tasks. Part of the formal role of a position is given by specifying what tasks are connected to the position. The formal role of position p is defined by the digraph which contains p and all elements of the H, P, and T graphs adjacent with p.

In Figure 4, the formal role of position $p_1$ consists of

(i) the assignment relationship $(h_1, p_1)$

(ii) the set of power relationships $\{(p_1, p_2), (p_1, p_3)\}$

(iii) the set of task allocation relationships $(p_1, t_1), (p_1, t_2)$

In an actual group, with a fixed number of positions and a fixed number of tasks, the allocation of tasks to positions may vary considerably. Consider a simple structure with two positions $(p_1, p_2)$ and two tasks $(t_1, t_2)$.

Figure 5 shows the possible methods of allocating tasks to positions so that at least one task is allocated to each position.

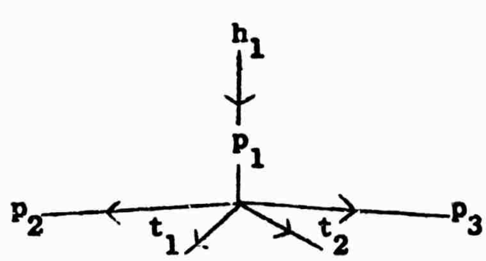


Figure 4.

Relationships on position $p_1$

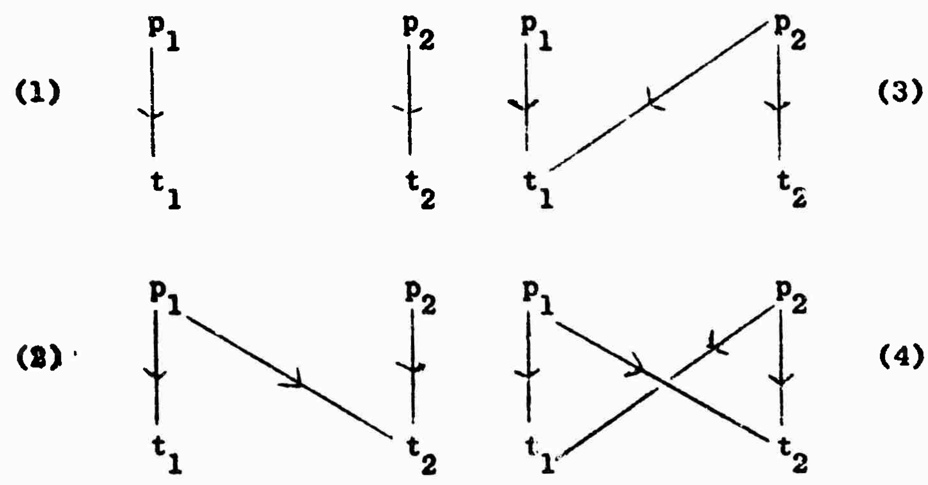


Figure 5.

P-T Digraph

Inspection of these diagrams at once suggests a more precise way of specifying what is meant by "degree of co-operation." Instead of the word "co-operation" we shall use "collaboration," which is a neutral term.

If a joint allocation of a task to a position is made, this requires that $h_1$ and $h_2$, in position $p_1$ and $p_2$, must collaborate . Therefore, one can investigate:

(a) the degree of collaboration between $p_1$, $p_2$ demanded by the structural role system

(b) the degree of actual or fancied collaboration.

Clearly, some situations demand more collaboration than others. Thus, in Figure 5, situation 4 requires more collaboration than situation 3, which in turn requires more collaboration than situation 1, They differ on a dimension of inter-position collaboration (as distinct from inter-task co-ordination which will be discussed later).

For ordering groups on the degree of inter-position collaboration ($C_{pt}$), it is desirable to have a formula which gives zero value to situations like situation1, where there is no sharing of tasks at all, and a maximum value of

1 to situations where all positions share all tasks.

A formula[7] which satisfies this requirement is

$$C_{pt} = \frac{\sum_{j=1}^{n} id(t_j) - n}{n\,(m - 1)}$$

where $id(t_j)$ = the in-degree of points $t_j$,

i.e., the number of lines to $t_j$ from the P-graph

n = number of tasks

m = number of positions.

The values for $C_{pt}$ for the situations in Figure 5 are

| Situation | $C_{pt}$ |
|---|---|
| 1 | 0.0 |
| 2 | 0.5 |
| 3 | 0.5 |
| 4 | 1.0 |

Sometimes tasks require inter-position co-ordination together with, or instead of inter-position collaboration. Co-ordination between positions is required because the sub-tasks are ordered by precedence relationship. Consider a group with two positions ($p_1$, $p_2$) and four sub-tasks ($t_1$, $t_2$, $t_3$, $t_4$). Some of the ways in which the positions may be allocated to the sub-tasks are shown in Figure 6.

For a given T graph, Figure 6 shows that the degree of "mesh" of the task systems of $p_1$ and $p_2$ may vary considerably. In (1) and (3), these systems are

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7. I would like to acknowledge the assistance of S. Pelczynski in the derivation of this formula.

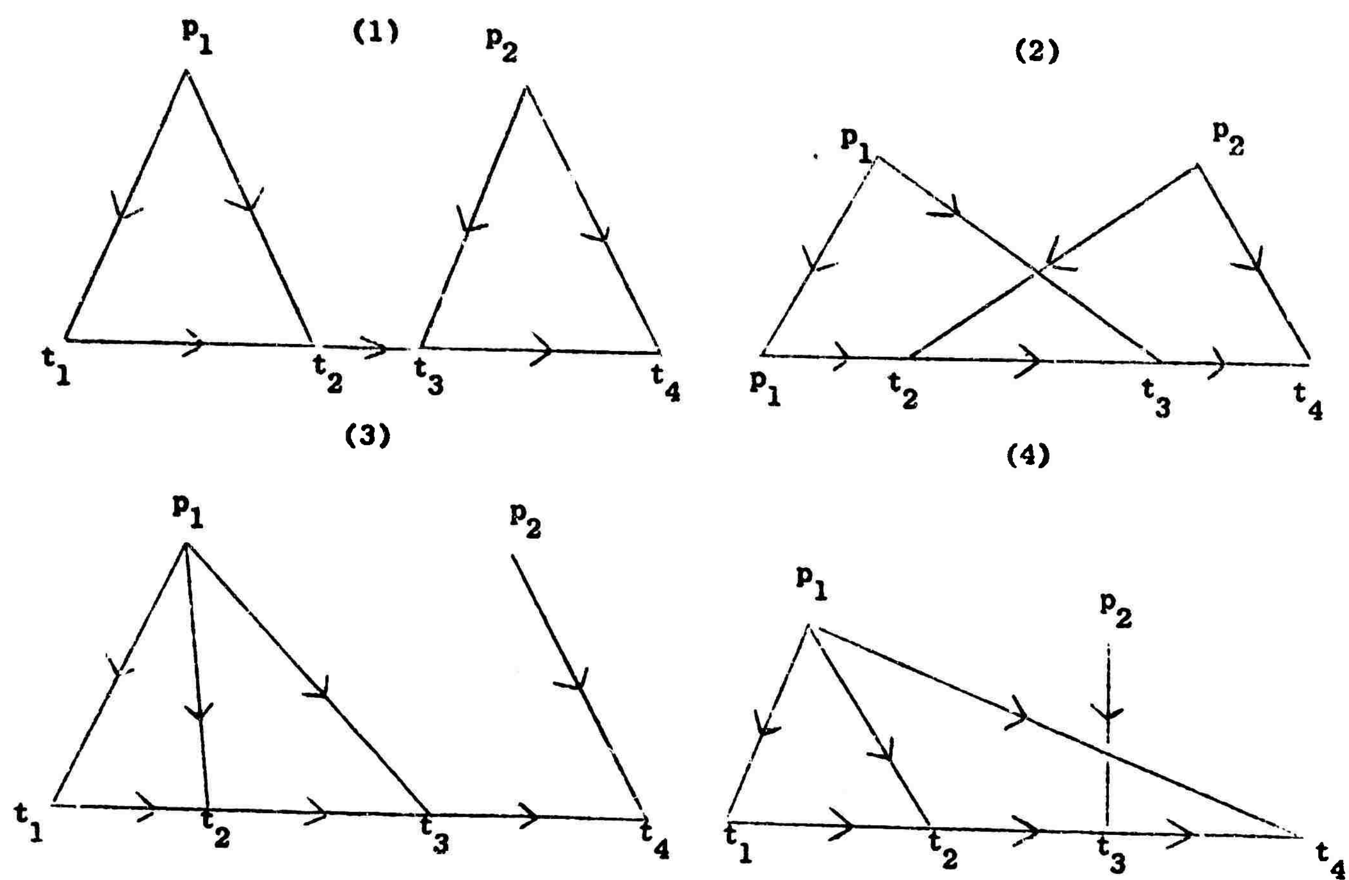


Figure 6.

Combined P-T, and T Digraph

temporally separated, but in (2) and (4) co-ordination is required if the total task is to be completed.

The amount of inter-position co-ordination not only depends, however, on the particular allocation of tasks to positions. It also depends upon the T graph. Figure 7 depicts digraphs showing some of the ways in which the T graph may produce different kinds of inter-position co-ordination.

A quantitative index of inter-position co-ordination can be derived using matrices[8]. Let $[TT]$ be the adjacency matrix for the task precedence digraph. In this matrix, the rows and columns correspond to sub-tasks and the entry

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[8] For an outline of the connections between digraphs and matrix operations, see Harary, Norman, and Cartwright (1965, ch. 5).

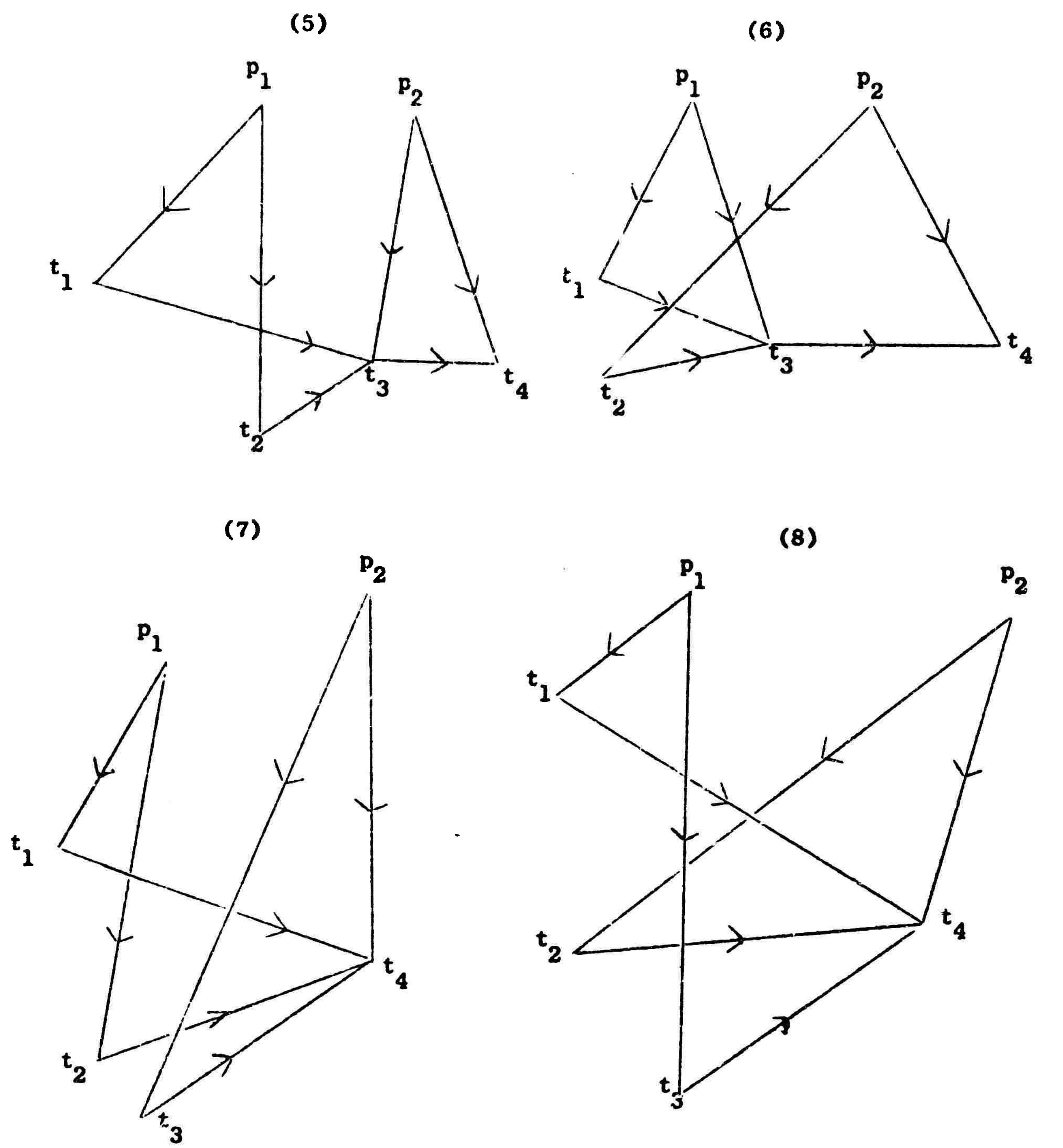


Figure 7.

Combined T and P-T Digraphs

$t_i t_j = 1$ if line $t_i t_j$ is in the T graph, while $t_i t_j = 0$ if line $t_i t_j$ is not in the T graph. Let $\left[PT\right]$ be the task allocation matrix where entry $p_i t_j = 1$ if sub-task $t_j$ is allocated to $p_i$ and entry $p_i t_j = 0$ if sub-task $t_i$ is not allocated to $p_i$.

Let $\left[PT\right]^1$ be the transpose of this matrix. This is obtained from $\left[PT\right]$ by interchanging its rows and columns. Thus, the $i$, $j$ entry of $[PT]^1$ is the same as the $j$, $i$ entry of $[PT]$.

Consider the digraph (1) in Figure 6 (reproduced as Figure 8).

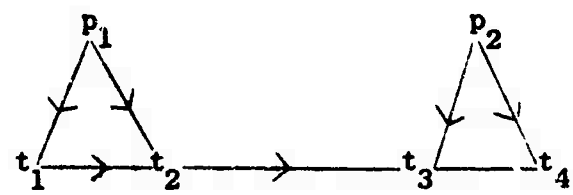


Figure 8.

Combined T and P-T Digraph

For this digraph, the corresponding matrices are

$$[TT] = \begin{array}{c} \\ t_1 \\ t_2 \\ t_3 \\ t_4 \end{array} \begin{array}{c} \begin{array}{cccc} t_1 & t_2 & t_3 & t_4 \end{array} \\ \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} \end{array} \qquad [PT] = \begin{array}{c} \\ p_1 \\ p_2 \end{array} \begin{array}{c} \begin{array}{cccc} t_1 & t_2 & t_3 & t_4 \end{array} \\ \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 \end{bmatrix} \end{array}$$

$$[PT]^1 = \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \\ 0 & 1 \end{bmatrix}$$

Using matrix multiplication, the matrix $[PT]^*$ is obtained.

$$[PT]^* = [PT] \cdot [TT] = \begin{array}{c} \\ p_1 \\ p_2 \end{array} \begin{array}{c} \begin{array}{cccc} t_1 & t_2 & t_3 & t_4 \end{array} \\ \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \end{array}$$

The $[PT]^*$ matrix gives for any $p_i$ the number of paths of length 2 connecting $p_i$ to $p_j$. The number of paths of length 2 from $p_1$ to $t_2$ in the digraph is 1, and this is shown in entry $p_1t_2$ of the $[PT]^*$ matrix. The number of paths of length n from $p_i$ to $t_j$ is given by entry $p_it_j$ in the matrix formed from $[PT] \cdot [TT]^{n-1}$.

The matrix $[PP]$ is obtained by multiplying $[PT]^*$ by $[PT]^1$.

$$[PP] = [PT]^* \cdot [PT]^1 = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$$

<u>The entry $p_ip_j$ of this matrix gives the number of times a sub-task allocated to $p_j$ must follow consecutively a sub-task allocated to $p_i$.</u>

In Figure 8, $p_1$ "changes over" to $p_2$ on the completion of $t_2$. Also, $p_1$ changes to $p_1$ on the completion of $t_1$. As shown, in $[PP]$, entries $p_1p_2$, and $p_1p_1$.

The matrices associated with digraphs (2) - (8) are listed below. The interpretation holds for all cases.

(2) $[PP] = \begin{bmatrix} 0 & 2 \\ 1 & 0 \end{bmatrix}$ (3) $\begin{bmatrix} 2 & 1 \\ 0 & 0 \end{bmatrix}$

(4) $\begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$ (5) $\begin{bmatrix} 0 & 2 \\ 0 & 1 \end{bmatrix}$

(6) $\begin{bmatrix} 1 & 1 \\ 1 & 0 \end{bmatrix}$ (7) $\begin{bmatrix} 0 & 2 \\ 0 & 1 \end{bmatrix}$

(8) $\begin{bmatrix} 0 & 2 \\ 0 & 1 \end{bmatrix}$

An index of inter-position co-ordination will increase as the number of "changes" from $p_i$ to $p_i$ increases. Also, for a fixed number of such changes, the index should be greater where the number of positions is less. An inverse index that seems to fit their requirements well is

$$CO_{pt} = \frac{\text{Sum of entries in main diagonal}}{\text{Sum of all entries}}$$

$$\text{i.e.,} \quad CO_{pt} = \frac{\Sigma \text{ diagonal}}{\Sigma \text{ total}}$$

The values for $CO_{pt}$ for the situations in Figure 6 are

| Situation | $CO_{pt}$ |
|---|---|
| 1 | 0.67 |
| 2 | 0.00 |
| 3 | 0.67 |
| 4 | 0.33 |

This means that inter-position co-ordination is greatest for situation 2 and least for 1 and 3, with 4 intermediate.

A big advantage of an index such as $CO_{pt}$ is that it can be calculated from quite complicated digraphs. $CO_{pt}$ for a complicated task will be calculated thus. Suppose that a given group task can be divided into two sets of tasks such that any task of the second set can only be completed if one or more tasks of the first set are completed. This type of situation could occur when the first set of tasks required observations of pointer reading, e.g., in an airplane cockpit, and the second set of tasks involved instrument adjustments. An instrument adjustment could only be made if, say, two pointer observations had been made. Let the total number of tasks be 12, and the number of positions be 3. A possible T graph is shown in Figure 9.

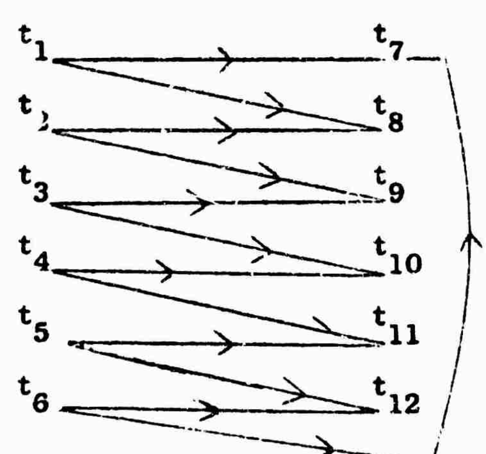


Figure 9.

T graph

A possible P graph is shown in Figure 10.

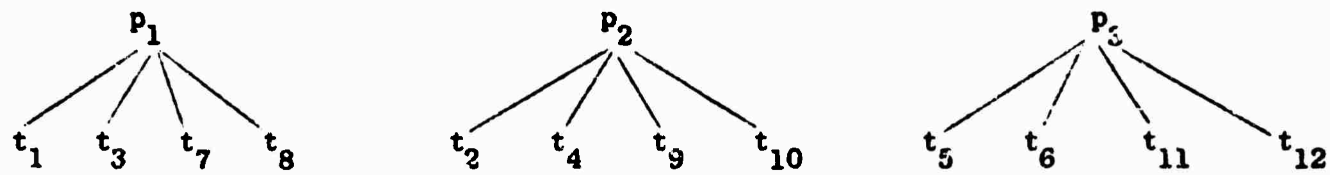


Figure 10.

P-T digraph

For this situation $\begin{bmatrix} PP \end{bmatrix} = \begin{bmatrix} 2 & 2 & 0 \\ 1 & 2 & 1 \\ 1 & 0 & 3 \end{bmatrix}$ and $CO_{pt} = 7/12 = 0.58$.

Other indices could be constructed from the $\begin{bmatrix} PP \end{bmatrix}$ matrix. Thus, a task load index could be given by the total sum of all entries.

3. <u>Task-Task-Relations</u>

The relationships between the tasks of a group may be depicted in a T graph, the points of which are tasks and the directed lines of which stand for precedence relationships----the order in which the tasks are to be done. For example, Figure 11 represents a possible T graph.

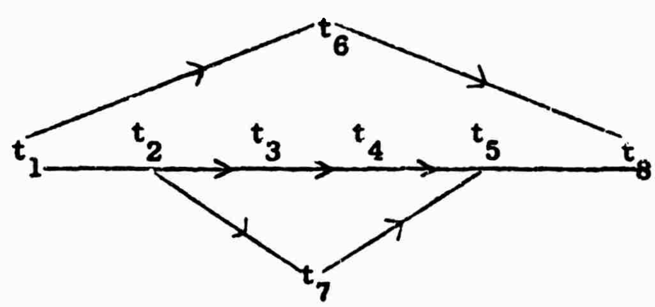


Figure 11.

T graph

The job has a beginning ($t_1$) and an end ($t_8$), and the completion of the whole task system is the goal of the group. It is possible to reach $t_8$ and attain the goal by three alternate complete paths. These are $t_1$, $t_6$, $t_8$;

$t_1$, $t_2$, $t_3$, $t_4$, $t_5$, $t_8$; $t_1$, $t_2$, $t_7$, $t_5$, $t_8$. From the T-graph it is possible to develop further indices which are useful for the comparative analysis of tasks.

Consider the notion of inter-task co-ordination, that is, setting the tasks in order so that the goal might be reached. Intuitively, it appears that a group task requires more co-ordination as the number of precedence relationships between tasks increases. Consider a 4-person group with four tasks such that each person has one task. The possible ways of ordering the tasks are set out in Figure 12.

The digraphs set out in Figure 12 are incomplete T-graphs because no beginning task has been specified. For calculating an inter-task co-ordination index, these initial tasks will be left out. The graphs themselves resemble the types of networks used for studies of communication. The inter-task-co-ordination index can be expressed as the sum of the distances from one point to all others, summed over all points. For instance, in graph 1, the distances from $t_1$ to $t_2$, $t_3$, $t_4$ respectively are 1, 2, 3. The distances from $t_2$ to $t_3$, $t_4$ are 1, 2 respectively. The $C_{tt}$ for graph 1 then is

$$(1 + 2 + 3) + (1 + 2) + (1) + (0) = 10.$$

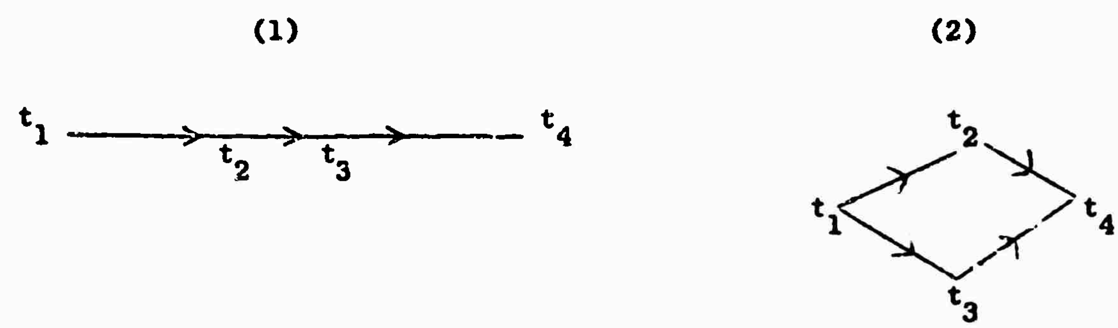


Figure 12.

Incomplete T-graph of possible precedence orderings of four tasks

(Continued on page 33)

(3) (4)

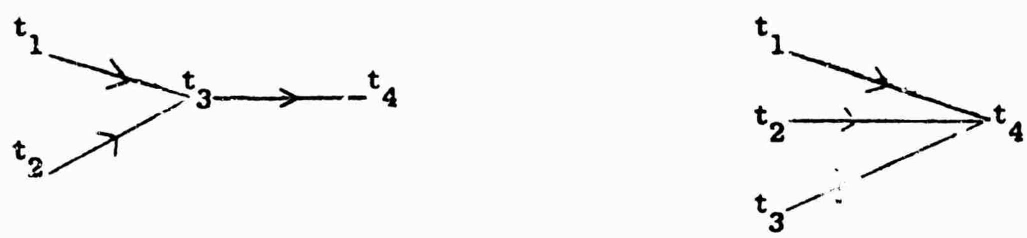


Figure 12.

Incomplete T-graph of possible precedence orderings of four tasks

$C_{tt}$ for Figure 12 examples (2), (3) and (4) are 8, 7, and 3 respectively. These figures are taken to mean that the distribution of tasks as in (1) demands more inter-task co-ordination than for (4), while (2) and (3) make intermediate demands.

Formally, then, the $C_{tt}$ index is constructed by (a) forming the digraph D consisting of all tasks except the beginning task; (b) calculating the $C_{tt}$ index value from

$$C_{tt} = \sum_{i=1}^{i=1} a_i$$

where n = number of tasks in the sub-set of tasks which excludes the initial task. $a_i$ = the distance sum from task $t_i$ and is equal to the sum of the finite distances ($t_i$, $t_n$), for all i, n.

Another property of the T-graph depicted in Figure 12 is the number of alternative paths from the beginning to the end. It would be desirable to have some method of finding the number of alternate paths in a group task (cf. goal path multiplicity, Shaw (1963) ). It appears possible to use some theorems of digraph theory developed by Harary, Norman, and Cartwright (1965). The theorems are concerned with the number of paths of given length in a digraph. Consider digraph (2) in Figure 12. The points and lines of this digraph can be represented by an adjacency matrix (d) in which the rows and columns correspond to points of D and the entry $a_{ij} = 1$ if line $t_i t_j$ is in D, while $a_{ij} = 0$ if $t_i t_j$ is not in D.

$$A(D) = \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

In order to calculate the number of point-line sequences in D of length n, the nth power of the matrix is computed. In $A(D)^n$ the i, j entry is the number of sequences in D of length n from $t_i$ to $t_j$. A point-line sequence is an alternating sequence of points and lines which begins and ends with a point and has the property that each line is preceded by its first point and followed by its second point. There is no restriction on the number of times a point or line may be repeated in the same sequence. Not all sequences are paths, since it is possible for the same point to be encountered more than once.

Let $P_n$ be the matrix whose i, j entry is the number of paths of length n from $t_i$ to $t_j$. A sub-graph $D_j$ is now specified which is obtained from A(D) by replacing every entry in the $j^{th}$ row and $j^{th}$ column of A by 0. Let $P_n(D_j)$ be the matrix of n-paths in $D_j$. According to Theorem 5.26 (Harary, Norman, & Cartwright, 1965) the matrix $P_n$ of n-paths of digraph D may be expressed in terms of the matrices of (n-1) paths of each of its sub-graphs $D_j$ by specifying its columns: the $j^{th}$ column of $P_n$ is the same as the $j^{th}$ column of the product $P_{n-1}(D_j) \cdot A(D)$ for j = 1, 2, ....p.

This theorem will be illustrated using the digraph D with four points shown in Figure 12(2).

$$P_1(D) = \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} \qquad P_1(D_4) = \begin{bmatrix} 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$P_1(D_2) = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix} \qquad P_1(D_1) = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$P_1(D_3) = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Calculating the $j^{th}$ column of the product $P_1(D_j) \cdot A(D)$ for $j = 1 \ldots 4$ the matrix of two paths of D is found to be

$$P_2(D) = \begin{bmatrix} 0 & 0 & 0 & 2 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

This matrix indicates that there are only two paths of length 2 in D and these are both from $t_1$ to $t_4$, as can be verified by inspection in this simple case.

The relation of the above procedure to the "Critical Path Method" (Shaffer, et al., 1965) will be obvious.

Clearly, the specifications of the three indices for inter-position collaboration, inter-position co-ordination, and inter-task co-ordination give greater precision to the previously rather vague definitions of "co-operation" and "task complexity" or "task difficulty." Further investigation of the properties of the interaction between these indices is possible, but is beyond the scope of this report.

## Summary

A beginning has been made towards an analysis of group tasks. Structural role concepts are used to relate the task system to other elements of a group, and indices are derived to measure the amount of inter-position collaboration, inter-position co-ordination, and inter-task co-ordination demands. A way of conceptualizing goal path multiplicity in terms of digraph theory is also given.

A general problem in need of investigation is the manner in which a task system may generate different sets of relationships in the P graph and the H graph. One example is that when two positions have to collaborate in a task, a communication relationship must be set up between these two positions in addition to any power relationship already defined on them. These relationships in turn will generate one or more informal relationships such as liking, deference or admiration.

A practical problem associated with the application of this type of task analysis concerns the identification of sub-tasks. In order to draw a digraph representing an actual group task it is necessary, firstly, to identify the constituent sub-tasks and secondly, to specify the precedence relationship ordering these sub-tasks. In some groups, it is relatively easy to represent the group tasks, e.g., for an assembly line in an automobile factory. Before the finished product can be completed, there are a series of operations performed by men on machines and materials. These operations are either capable of being identified or are explicit in the production plan. Furthermore, precedence relationships are generally explicit or are obvious from the actual layout of the material flow system.

For other tasks, the sub-tasks and precedence relationships cannot be easily inferred from observation of physical operations or material flow system. In problem-solving tasks, the sub-tasks may be best inferred from an analysis of the problem itself. Necessary steps in reasoning or calculating are generally identifiable.

In some tasks, however, neither physical nor logical operations may be used as a basis ofr drawing the T graph. Theoretical analysis, rather than "empirical" or "logical" analysis must be used. An example is a creative task. When a novel product is required, then there are no routine physical or logical sub-tasks. If a T graph is to be drawn, then it must be done with a particular theory of the creative process. Thus, the procedures for applying this task analysis may vary according to the type of task. A further difficulty is the level of analysis to be used. For a discussion task, should it be represented as one task, "discussion," or a number of sub-tasks (e.g., opinion-expressing, opinion-evaluating, etc.)? What level of analysis is used depends partly on the theoretical problem being investigated. So, generally, the interpretation (or operational definition) given to "sub-task" depends on the type of task, the purpose of the investigation, and the careful ingenuity of the investigator.

It is important to note however, that this problem of the level of analysis is not a difficulty unique to the structural role thoery approach to task description. Indeed, the problem is general whereever operational definition is used in the absence of established conventions for measurement. Within this limitation, it appears that the method of task analysis described in this report represents a substantial advance in that it

(a) deals with a comprehensive set of group elements and relationships

(b) provides a way of relating the task system to group structure and process

(c) develops a set of indices to describe some of the ways in which persons and positions in a group may be related to the task structure.

These indices give <u>precise</u> quantification and may be used quite generally to describe the task structure of a wide range of groups.

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13. ABSTRACT

In this report, it is argued that description and classification of group tasks can best be approached from a theoretical rather than empirical or factor analytic perspective. It is pointed out that previous attempts at task classification generally focus on one of three aspects of the task and group situation. The literature of group task analysis dealing with each of these aspects is then reviewed, and it is pointed out that each kind of task classification can be comprehended as an attempt to discriminate different relations existing between various elements of the task and group structure. The contribution of these attempts to a theoretically useful taxonomy of tasks is evaluated.

Structural role theory is introduced as a theoretical framework which leads to a system for classifying tasks. Digraph theory and matrix algebra are then applied to the problem of task definition, and indices for the measurement of some important group task dimensions (inter-position collaboration, inter-position co-ordination, inter-task co-ordination, and goal path multiplicity) are derived. The report concludes with a brief discussion of the problems and advantages of application of the structural role theory method of task analysis.

14. KEY WORDS

Group tasks
Structural role theory
Co-operation
Goal path multiplicity